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Impact of clear waters parasites on the biological wastewater treatment

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ABSTRACT

In wastewater treatment plants (WWTP), it is common to bypass non-compliant effluents based either on a visual estimate or on variations of the global parameters, in order to preserve the water biological treatment. This is often adopted when these parameters increase or an apparent change in the color of the influencers feeding the treatment plant. However, the dilution of wastewater by the clear waters attracts no attention and no alarm management position. Consequently, the main purpose of this study is to draw the attention of the WWTP managers to this fact often classified as not dangerous and not alarming, the effects of feeding disturbances and nutritional deficiencies caused by the presence of clear waters considered as parasites, will be evaluated on the treatment efficiency, the microbial activity, the flocculation status, and the microbial morphology, using a semi-continuous reactor, fed by a synthetic substrate obtained after leaching of 5 g L^{-1} animal feed for 4 h. The nutrient deficiency caused by the introduction of clear water into the sanitation networks causes not only the excessive proliferation of filaments by reaching a filamentous index (FI) of 5, but also the opening of microbial floc. Decantation was completely reduced and a decrease in the maximum exogenous respiration of 92.55% was recorded when the nutrients in the synthetic substrate were reduced by a factor of 1/10.

Keywords: Wastewater treatment; Food disturbances; Respirometric test; Flocculation state; Microbial activity

1. Introduction

The activated sludge is subject to qualitative variations which often make the good separation of purified sludge-water in the decanter precarious. The interruption or incomplete flocculation of biological buildings is the cause of a multitude of reasons, which can act in isolation or in synergy. These agglomeration difficulties can be grouped into two main classes, non-biological dysfunctions to mention sludge deflocculation, light flocs, floating materials, active tension foams, start-up foams, and non-biological dysfunctions mainly bulking and biological mosses, a classification was developed by Wanner and Grau [1], which is mainly based on the relationship between the conditions of the environmental medium (oxygen concentration, sludge age, the aerobic or anaerobic condition, etc.) and the predominance of certain filaments, which have been identified by several authors [2–4], with the aim of effectively and quickly remedying, but unfortunately an accumulation of dysfunctions is often encountered in the majority of WWTPs.

The local WWTP of IBN ZIAD, 12 km far from the city of Constantine (East of Algeria), has frequently encountered problems of settling, like the dispersed and non-flocculated growth of the biomass, hence often insufficient size, a viscous state of the sludge and a partial or complete bulking.

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In order to establish any links between the operation of the WWTP and observed biological malfunctions, a thorough reading and analysis of data from this station over the past 5 y were necessary.

A large variation in the monthly flowrates was observed with significant differences between the lowest and highest values which represented 38.24% and 94.98%, respectively, of the nominal flowrate value of 800 L s^{-1}. The monthly flowrates in dry weather are sometimes more important than those in rainy weather, due to the discharge of clear water into the network supplying the plant (Fig. 1).

Particular attention was paid to the variation of the organic load in the influent of the WWTP, expressed in total suspended solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD), by considering values for the last 5 y.

Large discrepancies were also recorded between the minimum and maximum TSS values and the biodegradable and non-biodegradable organic loads, as well as large fluctuations in the monthly quantities where for instance, for the first quarter of the 4th year of monitoring, the amount of TSS increased almost doubled between January and February, then decreased in March by 36% of the value recorded in February. The same trend was recorded between July and August of the same year. Also, the estimated biodegradable load in BOD decreased by 55% between July and August then rose by 45% for the same year. As previously mentioned this could not be caused by seasonal variations but rather by the presence of clear waters considered as parasites causing abrupt dilutions in organic feeds to the treatment plant (Tables 1 and 2). However, the biodegradability of the wastewater supplying the local plant was almost constant during the last 5 y of monitoring and the ratio of the biodegradability (BOD/COD) was varying between 0.27 and 1.23 with an average of 0.502, a value between 0.3 and 0.8 indicating an easy biological treatment of the wastewater [5].

The parasite waters may have several origins such as irrigation channels, clear water coming from the infiltrations of drinking water networks, and rainwater. These waters can generate a high dilution of the raw effluents and a considerable hydraulic load as well as an imbalance between the organic and the hydraulic load, inevitably causing malfunctions on each of the unit operations of the plant.

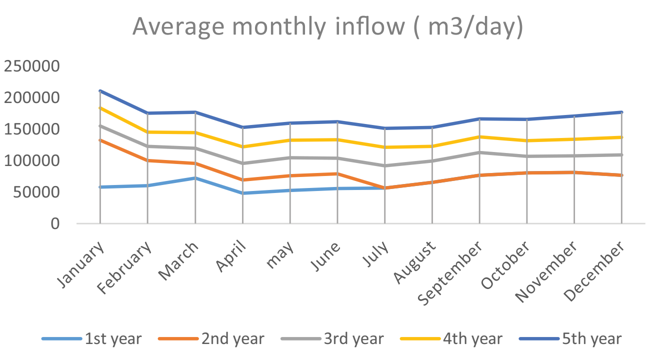


Fig. 1. Average monthly inflows for the last 5 y (IBN ZIAD WWTP).

Although the problems are different from one municipality to another, the problem of abandoned water particularly during dry weather is general and amplifies those due to heterogeneity or the variability of the composition of wastewater, particularly from networks receiving discharges from different industrial and residential sources, the absence of flow regulation basins, etc. (case of the local zoomed plant).

The nutrient deficiency usually concerns nitrogen or phosphorus and most often is associated with the discharge of industrial wastes that are rich in soluble biodegradable carbon fraction but deficient in proper quantity and quality in at least one nutrient [6].

Several past studies considered the settling problem linked to nutritional perturbations in WWTPs, and the first publications referring to biological problems date back to 1932 when Donaldson [7] assimilated the filamentous microorganisms to garden weeds, and found that their presence in large numbers limited settling, research is still going on to study this type of biological malfunction where this problem arises from time to time despite the efforts made to improve and control the WWTPs [8–11].

The purpose of this study is to determine the impacts of these disturbances in the plant feeding caused by clear water parasites, on the biological treatment of urban wastewater, on the microbial activity, on the morphological presentation of sludge and on their settling ability, and to draw the attention to the managers of the WWTP which do not especially have regulatory basins that this type of disturbance caused by clear waters can lead to a delicate situation.

2. Materials and methods

2.1. Used reactor and the applied experimental program

The experimental program was be carried out in a pilot consisting essentially of a transparent PVC cylindrical aeration tank, 20 L in volume, provided with a ball-type discharge valve, an agitator, a four blades stainless steel turbine type linked to an electric motor, varying the stirring speed between 20 and 400 rpm and an aquarium porous coil air diffuser, spread on the bottom of the driver, linked to a vacuum pump ensuring the continuous supply of air (Fig. 2). The reactor was operated in semi-continuous mode and fed with a synthetic substrate.

According to the objectives set for the present study, the experimental approach consisted of bringing the sludge collected at the local WWTP into contact with a synthetic substrate, after reaching the adaptation, and improving the degradation, microbial activity, and flocculation status by maintaining the same operating conditions as the sludge retention time (SRT) of 12 d, the hydraulic retention time (HRT) of 1.6 d and a COD_T between 600 and 700 mg L^{-1} and a ratio C/N/P of 100/5.58/0.0139, a food disturbance program was applied, the first of which was the major nutritional food deficit (nitrogen) and the second the dilution of the three major nutrients C, N, and P by clear water (Fig. 3).

2.2. Analytical procedures

The flocculation state before and after each step of the applied experimental program was evaluated mainly through the four following parameters:

- The turbidity of the supernatant after half an hour of settling.
- The filamentous index (FI) where according to the abundance of the filaments, a global or specific index to each species can be assigned [6,12,13].
- The capillary suction time, a technique developed by Gale and Baskerville [14], on a small scale as a practical and convenient means of measuring the filtration ability without resorting to an external source of pressure or suction. This ability is closely related to the size distribution of the microbial flocs and their state of aggregation [15,16]. Since the adaptation of the analysis by CST meter as a quantitative measure of the properties of different suspensions, it has known a wide field of application, passing through the evaluation of the mechanical stability of oil drilling [17], the study of the relationship between the rheological behavior of sludge and its dewatering [18], until the optimization of polymers, for the improvement of the flocculation quality of the suspensions [19].
- The values of sludge volume index and its volume index which is the volume of the sludge after 30 min of settling relative to the unit of mixed liquor suspended solids (TSS), often expressed in mL g^{-1} of TSS [20]; this index can also be expressed only through the volume occupied by an initial liter of sludge after 30 min of settling.

The lowest values of the capillary suction time and the turbidity of the supernatant correspond to the best quality of sludge and better settling, whereas the highest values of the filament index and the sludge volume index (or volume index) correspond to poor quality of the sludge, hence disturbances in the settling.

Respirometry was the tool used to quantify the activity of biomass in the various stages of the followed experimental program. Generally, it is based on the on-line measurement of oxygen consumption, oxygen uptake rate

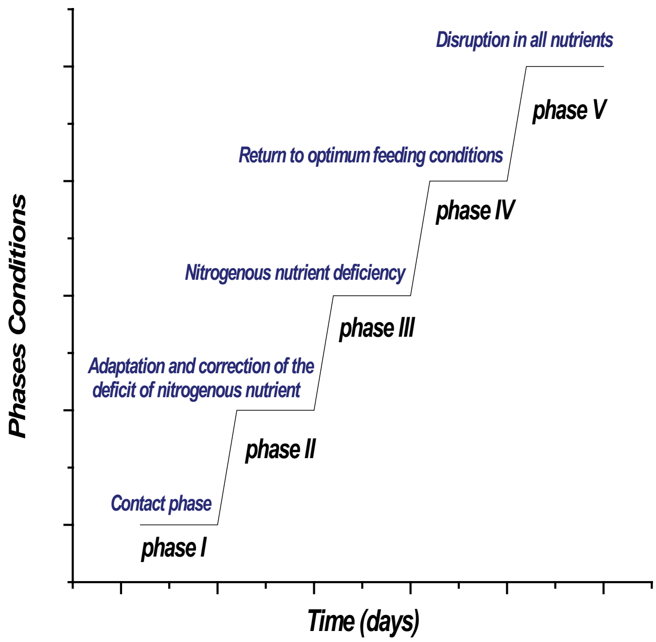
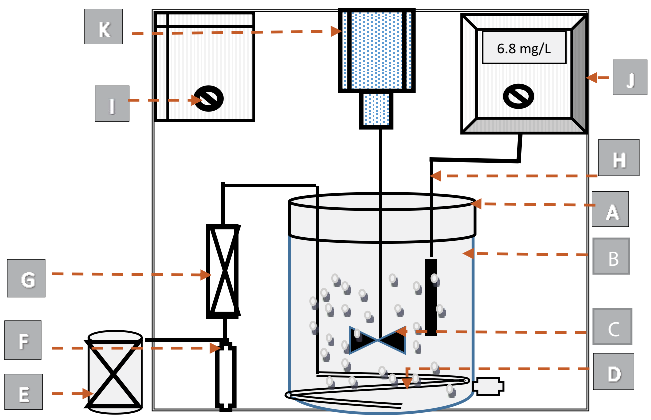


Fig. 3. Followed experimental program.



A:	Plastic cover of the container
B:	Transparent PVC cylindrical aeration tank of 20 L
C:	Mixing mobile of a 4 paddle turbine type in stainless steel of a diameter of 60 mm
D:	Serpentine type air diffuser
E:	Air pump
F:	An expansion device of compressed air scale 0–2 bar
G:	A flow meter on the air supply circuit
H:	Dissolved oxygen electrode
I:	Electronic converter and digital reading of the polarography Electrode
J:	Electronic controller of the mixing velocity
K:	Electric motor of the turbine type paddles with a variable rpm (20 and 400)

Fig. 2. Detailed scheme of the reactor used.

(OUR), by the bacterial purifying populations. Under aerobic conditions, microorganisms consume oxygen in proportion to substrate removal and biomass growth. The rate of respiration is the amount of oxygen consumed per unit volume and time [21,22].

The observation and the estimation of the geometrical parameters, characterizing the respirometric peaks play a key role in the detection and the instantaneous evaluation of the situation of the WWTPs, when they are facing certain malfunctions and to quote the initial slope of the peak, the peak height or maximum respiration OUR_{exomax} (mg O_2 L^{-1} min^{-1}) after injection of the amount of exogenous substrate and the peak area which is the amount of oxygen consumed QTO (mg O_2 L^{-1}) by the microorganisms to metabolize the injected substrate [23].

$$\mathrm{OUR}_T = \mathrm{OUR}_{\mathrm{exo}} + \mathrm{OUR}_{\mathrm{end}} \tag{1}$$

$$\mathrm{OUR}_{\mathrm{exo}} = K_L a \left(S_{\mathrm{end}} - S_0\right) - \frac{d\left(S_0\right)}{dt} \tag{2}$$

$$\mathrm{OUR}_T = K_L a \left(S_{\mathrm{OS}} - S_0\right) - \frac{d\left(S_0\right)}{dt} \tag{3}$$

The parameters: pH, total COD (COD_T), soluble COD (COD_S), TSS, VSS, salinity, electrical conductivity, NH_4, NO_2, NO_3, and PO_4 parameters were investigated before and after every step of the experimental program according to Standard Methods.

Several authors had used microscopic visualization and image processing as a tool census, characterization, monitoring, diagnosis, and remediation [13,24–26]. Microscopic observation was carried out for the different components of the sludge (interstitial fluid, microbial floc, and micro fauna) in the fresh state or in the state stained with Methylene blue, using a microscope with variable magnification (Infinity, Optech). These visualizations were carried out for the different samples in each phase and could give information about the state of flocculation, the presence of the filaments and the dimensions of the flocs.

2.3. Synthetic substrate

In theory, it would be ideal to use a substrate to which the biomass is already acclimated, but it is possible to use substrates which have very low latency phases, such as yeast extract, sodium acetate, and glucose for carbonaceous substrates and nitrogenous ammonia for the nitrogen substrate. Yeast extract has demonstrated its very rapid biodegradability compared to that of sodium acetate and glucose [27], since it contains micronutrients that promote bacterial growth, but unfortunately for continuously fed reactors for a long period of operation, another substrate should be used, that is more accessible, less expensive, and has characteristics close to urban wastewater.

For the necessary large volumes of synthetic wastewater for the pilot supply, a synthetic substrate obtained after leaching of an animal feed was used with a dose of 5 g L^{-1} and a contact time of 4 h. The time and the dose were optimized to obtain leachates of composition close to wastewater (Table 3). Nitrogen and phosphorus fractions were low in the obtained leachates, hence necessary additions to study the effect of nutrient deficits.

The use of this type of synthetic substrate not only had the advantage of using substrates with very low costs, supplying reactors mainly operating in continuous and semi-continuous modes but also to avoid increasing the salinity and the conductivity of the substrate in the reaction medium, a case encountered during the use of sodium acetate as carbon source, for instance.

2.4. Inoculum

The mixed liquor was collected in the last aeration basin of the biological treatment chain of the local WWTP, designed to treat a flow rate of 800 L s^{-1} of wastewater and rainwater collected in a unitary network.

Microscopic visualizations in the colored state (Methylene blue staining) were carried out in order to detect the initial state of the inoculum before the adaptation step. A low flocculation was observed with floc opening and minimal presence of filaments (FI = 1) with rather crowded interstitial fluid, an average perimeter and surface area of the flocs varying between 8.18 and 97.87 μm and 112.64 and 2,579.52 μm^2, respectively (Fig. 4a).

3. Results and discussion

During the entire experimental period, the temperature of the reaction medium and the pH varied slightly in ranges of 19.9°C and 23.8°C and of 7.41 and 7.98, respectively. The electrical conductivity and salinity in the aeration basin varied from 1,600 to 2,210 μS cm^{-1} and from 0.8% to 1%, respectively, which would consolidate the good choice of the used synthetic substrate.

For dissolved oxygen, a gradual decline was recorded from the end of phase III without reaching a very low value (≤2 mg L^{-1}), despite the fact that the oxygen supply was adequately provided throughout the experimental period.

3.1. Effect on the flocculation state of biological aggregate

Filamentous bacteria play an important role in the formation of flocculated sludge structures granting them more resistance to predation and hydrodynamic disturbances. However, when their density is too high, the apparent density of the aggregates can decrease, resulting in a decrease or even a complete alteration of the settling [4].

Microscopic observations were performed to monitor the morphology of organic aggregates and the presence of filamentous bacteria in each phase.

Initially during the adaptation phase (phase I) a series of microscopic visualizations were performed revealing, on the one hand, the minimal presence of the filaments which corresponds to IF varying between 0 and 1 and on the other hand a not correctly developed flocculation with a cloudy supernatant and a not well-defined sludge blanket (Fig. 4a).

In the synthetic substrate used, the COD was mainly in soluble form, the COD_S/COD_T ratio was 0.98. However, the nitrogen fraction was mainly in organic form (84.53%) which had to through an ammonification before being

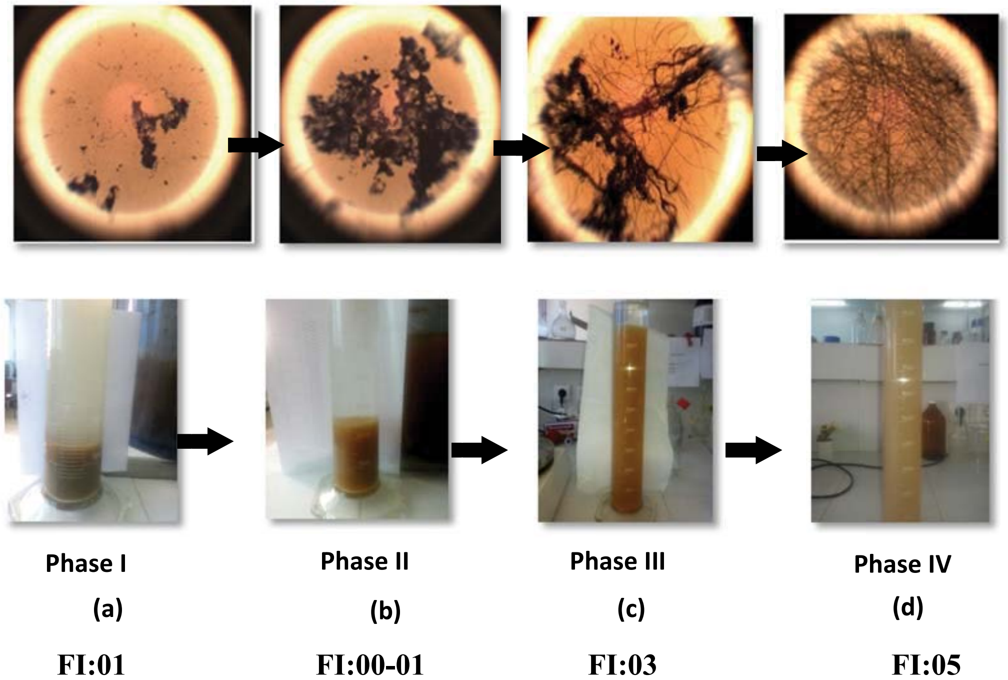


Fig. 4. Microscopic and macroscopic presentation of microbial flocs in the different phases: (a) before adaptation (start of experiments), (b) after adaptation and the correction of the deficit of nitrogenous nutrient, (c) after nitrogenous nutrient deficiency, and (d) after disruption in all nutrients.

assimilated by microorganisms [28]. The ammonium ions being the preferred nutrient source of nitrogen because of its high solubility in water and since it was immediately ready to be adsorbed and metabolized by bacteria [28], this nitrogen source was largely preferred to the organic form such as amino acids, so it was necessary to enrich the medium with the ammoniacal form in phase II, by changing the ratio C/N/P (COD/N–N_T/P–PO_4) from 100/5.58/0.0139–100/9.21/0.0139, respectively.

This state was improved after adding an ammonia nitrogen supply (phase II), the flocculation was more developed (denser and firmer aggregates), the interstitial liquid was more clear, and a very clear sludge blanket with an IF equal to 0 (Fig. 4b).

In phase III, a deficiency of nitrogen form (ammoniacal form) was imposed, the same indicators reported in the literature [28] concerning this nutrient deficiency in an activated sludge treatment process were observed. These indicators included the undesirable growth of filamentous organisms deficient in nutrients and the production and accumulation of nutrient-deficient biological mosses (021 N, 0041, 0092, 0581, 0675, 0803, 0961, *Haliscomenobacter hydrossis*, *Microthrix parvicella*, Nocardioforms filaments), a fraction of filamentous organisms oscillating between 1% and 20% is sufficient to create the most delicate problems of settling which is the bulking of sludge [29,30].

After nitrogenous nutrient deficiency (phase III), the number of filaments increased gradually, reaching an IF equal to 3. The nitrogen deficiency imposed after adapting the microorganisms to a regular nitrogen threshold for 10 d (phase II), favored the development of filamentous microorganisms.

Although this disturbance lasted only 4 d, the effect was very apparent microscopically and macroscopically, the sludge blanket significantly increased, inevitably causing a loss of solid (Fig. 4c).

Based on the results of microscopic visualizations, the reduction of purification yields from phase III was therefore due to the release of the extracellular polymer matrix which could represent up to 60% of the organic fraction of sludge, whereas the cellular biomass represented only up to 20% [31]. This has been observed macroscopically by the gradual increase in the viscous state of the mixed liquor.

Nutrient deficiency caused not only the excessive proliferation of the filaments but also the opening of the aggregate structure. The estimate of the effect of this perturbation on microbial activity was evaluated experimentally by respirometric tests.

After the correction of the nitrogen and the return to the conditions of good operation, the state of flocculation improved significantly and the filamentous index IF decreased by two units passing from 3 to 1 (phase IV).

The reduction of nutrients in the synthetic substrate feeding the reactor by a factor of 1/10 (dilution of wastewater by the water parasites and this factor was set according to the maximum variation in the organic loads of the influents of the plant) caused a complete proliferation of the sludge where the filamentous index reached its maximum value 5 and decantation was completely degraded (Fig. 4d).

It may also be noted that the reduction of oxygen concentration in the aeration basin, from phase III was due to the progressive proliferation of the filaments requiring more oxygen demand at the same time, because of their large exchange surfaces.

To explain the mechanisms of growth of filamentous microorganisms, under feeding disturbances or nutritional deficiency conditions, several hypotheses have been put forward. For instance, the competition between filamentous and non-filamentous microorganisms in case of low nutrient content or oxygen concentration, was based on the fact that the area/volume ratio (*A*/*V*) is more important for filamentous bacteria than flocs, thus facilitating mass transfer (nutrient) and correlatively growth rate [32]. The proliferation of filaments may be related to the ability of the filaments to pierce the flocs from outside to access the substrate in case of deficiency. This situation can lead to a more open and filamentous aggregation, whereas in the case of substrate abundance, more compact structures appear [30,33,34], and finally, some filaments, can have high storage capacities during periods of feeding disturbances, favoring and thus preserving their growth [35–37].

The sludge capacity, represented by the SVI, was to be measured in each phase of the experimental program. The SVI could be calculated only at start-up and during phase I and II, for the other phases, dilutions will be required to calculate this parameter (V_{30} > 250 mL).

The dilutions were not carried out but the follow-up of the settling volumes after 30 min of settling (V_{30}) was rather carried out. The increase of the settling volumes during phase III was explained in particular by a change in the morphology of the aggregates from the 1st day of nutrient disturbance (nitrogen) (Fig. 5).

The gradual increase in sludge number or settling volume was associated with an increase of one or more units in the overall filament index and alteration of the morphology of biological aggregates and interstitial fluid (Fig. 5a).

The follow-up of the state of the flocculation was also evaluated by two other parameters, the turbidity of the supernatant of the liquor taken from the reaction medium after half an hour of decantation and the capillary suction time. The latter made it possible to evaluate the rearrangement of the flocs in the inter-particle space (flocculation or deflocculation) by evaluating the filtration ability time of the liquor through a specific filter paper.

The values of the capillary suction time had been standardized by relating them to their concentrations of TSS (CSTS), since they had a considerable influence on the measurement of the capillary suction time [38].

The correction of the nitrogen deficiency in phase II was not very apparent in the CSTS measurements, but it was in the measurement of turbidity which clearly increased in the 1st day of disturbance, spending an average of 25.4 NTU in phase II at over 1,000 NTU in Phase V (Fig. 5c).

However, these disturbances were not too well-estimated by the capillary suction time since the state of

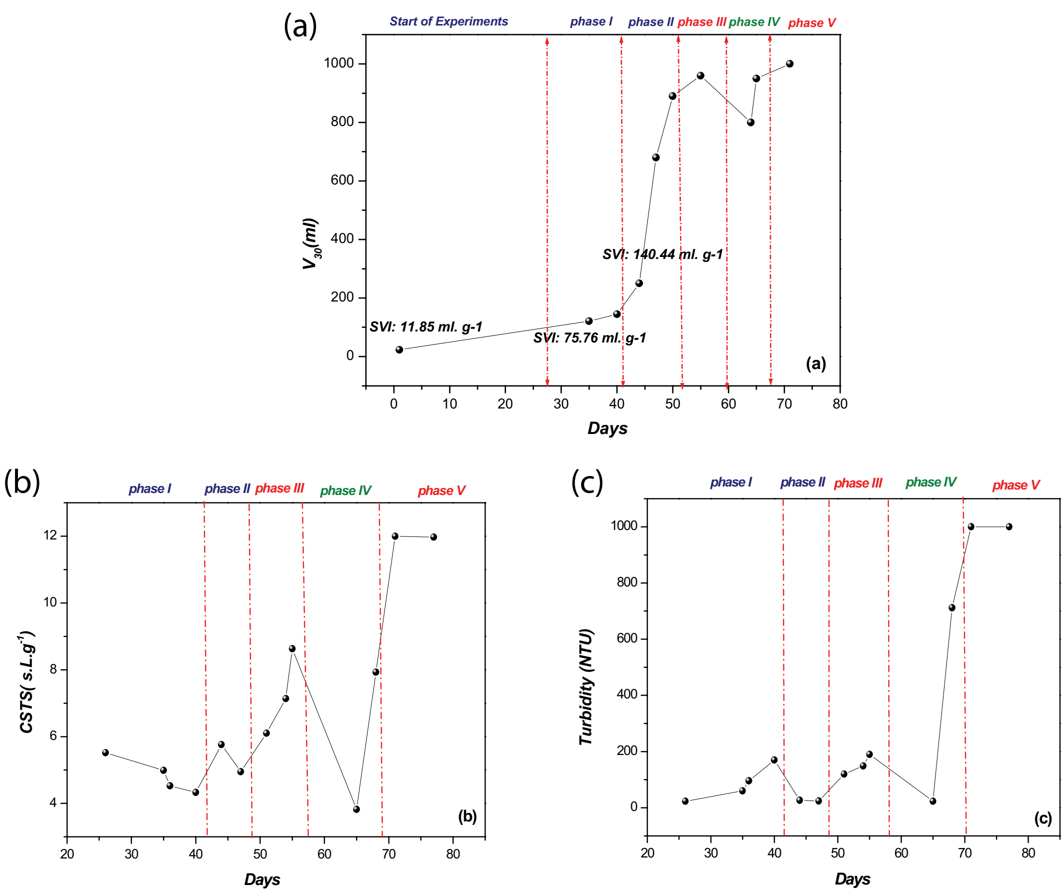


Fig. 5. Temporal Evolution of (a) V_{30} in each phase, (b) the standardized capillary suction time, and (c) the supernatant turbidity in the different phase.

flocculation gradually became lost from the 1st days of disturbance, passing on average from 5.35 s L g^{-1} in phase II to 11.98 s L g^{-1} in phase V (Fig. 5b).

This increase in capillary suction time particularly in phase V was rather due to the excessive proliferation of filaments (a weaving of filaments reducing this time). Although the precaution of standardizing the capillary suction time with respect to the concentration of TSS, was taken into account, except that this time was not standardized with respect to the viscosity of the reaction medium which gradually increased (based only on the visual estimation) to from phase III.

Although the disturbance in feeding caused enormous morphological changes inducing a reduction of the purification and settling capacities, remediation was reached by a correction of this deficit (phase IV).

3.2. Effect on the purification performance

Phase I was prolonged over a long period (39 d), but although the operating conditions were very favorable and the microorganisms seemed to be adapted (good activity and the mobility of some microorganism was observed microscopically), the treatment and decantation yields seemed to be unsatisfactory. As mentioned above a second phase (phase II) was imposed in order to improve the purification performances before applying the disturbances.

The improvement in purification performance was achieved by correcting the nitrogen deficiency in the synthetic substrate feeding the biological reactor, by an addition of excess nitrogen in the ammoniacal form (phase II).

The evolution of the abatement efficiencies of the various parameters of interest (COD_T and COD_S) are shown in Table 4 for the different monitoring phases. The nitrogen supply improved the state of the flocculation and also resulted in an improvement in the COD_T and COD_S abatement efficiency reaching 50.30% and 49.016%, respectively.

The purification yields were significantly reduced in the different phases following phase II, this could be due either to a reduction of the microbial activity or to a deflocculation of the microbial aggregates releasing their intracellular components and thus contributing to an increase of the carbon load, measured as COD_T or COD_S.

Although a remediation step was applied for 15 d by the return to optimal feeding conditions in phase IV, the purification performance did not reach the desired purification level, probably this was also due to the operating mode of the used biological reactor (semi-continuous reactor) or the reduction in the microbial activity (considered in the next section).

3.3. Effect on microbial activity

The microbial activity was initially carried out in order to follow the adaptation of the microorganisms to the injected exogenous substrate (leached substrate) and then it was used to monitor the activity of the microbial flora presented in different morphological aspects. The microbial activity was evaluated by respirometric tests carried out after incubation of the mixed liquor taken from the biological reactor in a continuous aerated respirometer [39].

The respirometric tests were carried out by injecting the synthetic substrate into the respirometer, at low S_0/X_0 ratios (0.04 mg COD/mg VSS) [40,41].

Respirometry tests allowed the estimation of oxygen transfer coefficients in the respirometer (K_La), endogenous respiration (OUR_{end}), maximal exogenous respiration (OUR_{exomax}), maximal total respiration (OUR_{Tmax}), and the total amount of oxygen consumed (QTO) [23]. These different parameters were evaluated in phase I, II, III, and V (Fig. 6).

It was noted that the endogenous release was performed by the sludge washing technique [42], for the first two respirometry experiences (liquor is taken in phase I and II) and by the technique of continuous aeration of the sludge for a time-varying between 16 and 24 h [43,44] before test, for the last two respirometry experiences (liquor taken in phase III and V), the second technique was applied because the increase in the sludge sail reducing the efficiency of the washing technique.

Initially, the amount of consumed oxygen and the exogenous maximum respiration were 58.608 mg L^{-1} of the respirometer reactor and 166.32 mg L^{-1} h^{-1}, respectively.

Table 1
Estimated monthly organic load expressed in TSS in the influents of the local WWTP for the last 5 y

Monthly TSS[a] (Tons)	1st year	2nd year	3rd year	4th year	5th year
January	7.43	12.4	2.94	5.736	–
February	13.1	7.77	3.03	10.40	5.261
March	8.49	5.79	2.98	6.615	4.956
April	5.29	4.80	5.04	6.361	4.287
May	7.68	7.17	5.70	7.670	4.531
June	4.28	5.82	4.94	5.480	5.167
July	6.56		5.61	6.092	4.544
August	7.02		6.45	3.493	6.017
September	6.26		4.15	4.656	5.526
October	1.24		4.72	4.662	5.106
November	1.48		5.54	3.557	4.603
December	8.39		6.35	3.355	4.080

[a]Monthly amounts of TSS were estimated by calculating the average of the daily quantities obtained and multiplying the daily concentration by the average daily flow.

A very interesting level of activity [45], where the amount of consumed oxygen increased by 24.37% when adding nitrogen (Table 2). This increase could be due either to the improvement of the microbial activity or to the nitrification of the nitrogen excess (increase of autotrophic activity microorganisms). However, it should be noted that a reduction in endogenous respiration estimated at 39.65% between phase I and phase II had been recorded as well as a reduction of the exogenous maximum respiration, since the availability of nitrogen would promote the synthesis (microbial multiplication of heterotrophs and autotrophs), hence a decrease in respiration. Two other respirometric tests were performed by reaching phase III and V and the results for these last two injections are shown in Table 5.

In addition to the morphological change of the microorganisms and after 62 d of experimentation (phase III), the microbial activity was reduced by 77.5% compared to the total quantity consumed and by 90.83% and 97.03% compared to the maximal exogenous and total respiration recorded in phase II, respectively.

This reduction was amplified after a reduction of a factor of 1/10 of the nutrients C, N, and P in the synthetic substrate feeding the reactor and was 91.52% compared to the total quantity consumed and by 92.22% and 92.55% in relation to maximal exogenous and total respiration, recorded in phase II, respectively.

Maximum respiration was significantly higher than endogenous respiration in phases I and II and despite the nutritional stress imposed, they remained higher but to a much lesser degree.

4. Conclusions

The nature of the influent supplying sewage treatment plants is directly related to sanitation networks which unfortunately are often altered either by the clear water parasites or the septicity of the effluents.

The data from the local WWTP (IBN ZIAD STEP) over the last 5 y had been used to identify two major causes that could disrupt the treatment process, citing the variation of the hydraulic load (sometimes caused by water parasites) and the variation of the organic load.

The purpose of this study was to explore the effect of food disturbances and nutritional deficiencies in the influent composition of WWTPs on the treatment efficiency, morphological status of microbial sludge, and their settling capacity.

To achieve these objectives, the experimental approach adopted consisted in analyzing the operation of a pilot of capacity of 20 L subjected to disturbances in the feeding of

Table 3
Composition of leachate animal food used to feed the biological reactor

Parameter	Average value
pH	7.6
Conductivity (μS cm^{-1})	1,472
Salinity (%)	0.8
Turbidity (NTU)	36.5
TSS (mg L^{-1})	483
VSS (mg L^{-1})	465
COD_T (mg L^{-1})	778.17
COD_S (mg L^{-1})	763.29
N–NO_3^- (mg L^{-1})	0.013
N–NO_2^- (mg L^{-1})	0.033
N–NH_4^+ (mg L^{-1})	6.72
N–N_K (mg L^{-1})	43.446
N–$N_{Mineral}$ (mg L^{-1})	6.766
N–N_T (mg L^{-1})	43.49
P–PO_4^{-3} (mg L^{-1})	0.1086
Ratio	
COD_T/N–N_T/P–PO_4^{-3}	100/5.58/0.0139
COD_S/COD_T	0.98
VSS/TSS	0.96

Table 2
Estimated monthly organic load expressed in BOD_5 in the influents of the local WWTP for the last 5 y

Monthly BOD_5[a] (Tons)	1st year	2nd year	3rd year	4th year	5th year
January	9.81	10.6	3.80	4.688	4.333
February	7.40	5.55	3.73	4.569	4.518
March	6.96	5.79	3.20	4.510	4.369
April	2.50	5.85	5.28	5.550	3.794
May	3.63	5.31	4.42	6.271	3.608
June	9.52	5.00	5.04	4.743	4.437
July			6.21	5.009	5.022
August			5.81	2.257	4.717
September			6.00	4.120	8.048
October			4.54	4.338	6.162
November			4.79	3.562	5.328
December	9.39		4.62	3.355	5.640

[a]Monthly amounts of BOD_5 were estimated by calculating the average of the daily quantities obtained and multiplying the daily concentration by the average daily flow.

one of the nutritive elements (nitrogen), or of the totality of the organic load.

The analysis of the pilot's operation during the five stages of monitoring clearly showed the effect of feeding disturbances on the morphological state of the sludge, on the settling capacity, and on the purifications estimated in terms of COD. However, despite the important effect of these disturbances on microbial activity, it still existed.

The effect was assessed by quantifying several parameters and the results showed that the stabilization of the purification system could only be achieved by stabilizing the purification conditions and the composition of the influent feeding the WWTP, particularly purification and biological basins.

The measurements carried out on the pilot for more than 77 d confirmed the effect of these disturbances in feeding on the decantation of the activated sludge, their morphological state, and on their activity. The main conclusions are:

- Despite the short duration of the imposed disturbances, their effects were very significant.
- Nutrient deficiency (N) led to excessive proliferation of filaments, an opening of the structure of the aggregates, and thus a release of intracellular constituents, causing a disturbance in the purification and the settling yields.
- The effect of the deficit of major nutrients C, N, and P (dilution by parasite water) was greater compared to nitrogenous nutrient deficiency.
- Remediation could be achieved by correcting nutrient deficiencies.
- The accumulation of problems that may arise in a treatment plant (variation of hydraulic loads and organic loads, disruption of the power supply) complicates and aggravates the problems in the treatment plants.

Therefore, maintaining a stable mass load over time is one of the main conditions of the stability of the purification performance of sewage treatment plants. By controlling the discharge of wastewater into the urban plant or by installing regulatory basins upstream of the treatment plants, it is possible to preserve the operation of the treatment plants and avoid the problem of bulking which is difficult to control afterward.

Symbols

BOD_5	—	Biochemical oxygen demand in 5 d, mg O_2 L^{-1}
COD_S	—	Soluble chemical oxygen demand, mg O_2 L^{-1}
COD_T	—	Total chemical oxygen demand, mg O_2 L^{-1}
CST	—	Capillary suction time, second
FI	—	Filamentous index
K_La	—	Oxygen transfer coefficient, Time^{-1}
NO_2^-/NO_3^-	—	Nitrite and nitrate concentration, mg L^{-1}
$N\text{–}N_K$	—	Kjeldahl–nitrogen concentration, mg L^{-1}

Table 4
Variation in COD_T and COD_S abatement performance throughout the experimental period

Phases	COD_T abatement efficiency	COD_S abatement efficiency
Phase I	16.52	15.77
	28.69	5.20
	37.94	64.98
	38.094	16.86
	21.79	25.86
	22.72	25.46
Phase II	50.30	49.016
Phase III	–15.11	–67.34
	–1.054	–3.89
	–5.83	–2.17
Phase IV	–5.40	–11.63
Phase V	–1.93	–11.20

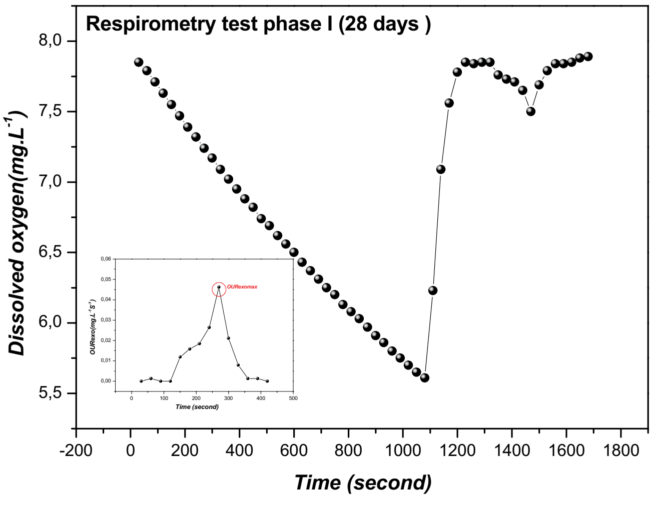


Fig. 6. Temporal evolution of dissolved oxygen and exogenous respiration in phase I.

Table 5
Parameters characterizing microbial activity in each phase

Parameter	S_{end} (mg L^{-1})	OUR_{end} (mg L^{-1} h^{-1})	K_La (min^{-1})	OUR_{exomax} (mg L^{-1} h^{-1})	OUR_{Tmax} (mg L^{-1} h^{-1})	QTO (mg L^{-1})
Phase I	7.85	8.352	7.92	166.32	665.28	58.60
Phase II	8.03	5.04	5.76	86.4	387.07	72.89
Phase III	8.5	3.54	8.85	7.92	11.46	16.40
Phase V	8.1	3.84	4.8	6.72	28.8	6.18

$N–NH_4^+$	—	Nitrogenous ammonia concentration, mg L^{-1}
$N–N_{Mineral}$	—	Mineral nitrogen concentration, mg L^{-1}
$N–N_T$	—	Total nitrogen concentration, mg L^{-1}
NTU	—	Nephelometric turbidity unite
OUR	—	Oxygen uptake rate, mg O_2 L^{-1} min^{-1}
OUR_{end}	—	Endogenous oxygen uptake rate, mg O_2 L^{-1} min^{-1}
OUR_{Tmax}	—	Maximum total respiration, mg O_2 L^{-1} min^{-1}
OUR_{exomax}	—	Maximum exogenous respiration, mg O_2 L^{-1} min^{-1}
PO_4^{-3}	—	Orthophosphate concentration, mg L^{-1}
QTO	—	Amount of oxygen consumed, mg/unit volume of the respirometric cell
S_0	—	Oxygen concentration, mg O_2 L^{-1}
S_{SO}	—	Saturated oxygen concentration, mg O_2 L^{-1}
S_{end}	—	Endogenous oxygen concentration, mg O_2 L^{-1}
SVI	—	Sludge volume index, mL g^{-1}
TSS/VSS	—	Total and volatile suspended solids, mg L^{-1}
V_{30}	—	Volume after 30 min of settling, mL

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